PERSPECTIVE NAVIGATION

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INTRODUCTION

The system which is here described aims to give a perspective picture of a certain number of elements abstracted from the picture of, say, a harbour as it would be seen by a ship's navigator in good weather. The system uses a number of low-power X-band transmitters. These are placed at strategic points in the area which is to be observed and are energized in sequence ; there may, for example, be 100 transmitters disposed in a congested area and these can be switched in rotation at 100 c/s. Suppose, for example, that a transmitter be placed at the location of each of the harbour lights of Figure 1. At night, in good weather,

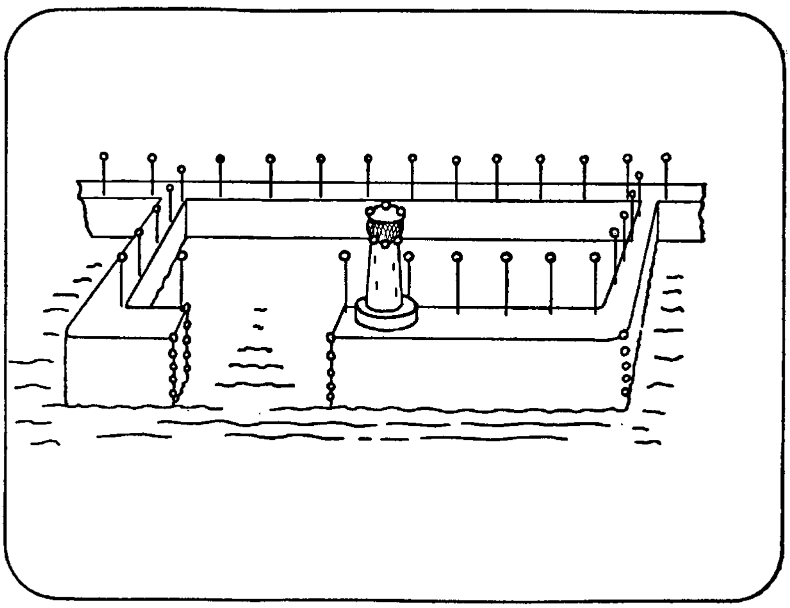

Fig. 1.

the lights will appear as shown in Figure 2. The present system gives a picture on the cathode-ray tube which, in all weathers including the worst fog, will appear as shown in Figure 3.

PRINCIPLE OF THE SYSTEM

Referring to Figure 4, if two aerials have phase centres at A_1 and A_2, spaced by a distance a, and if a plane wave of length λ is received from a direction at an angle θ to the axis of symmetry, then the phase difference between the waves received by the two aerials is

$$\frac{2\pi a \sin \theta}{\lambda}$$

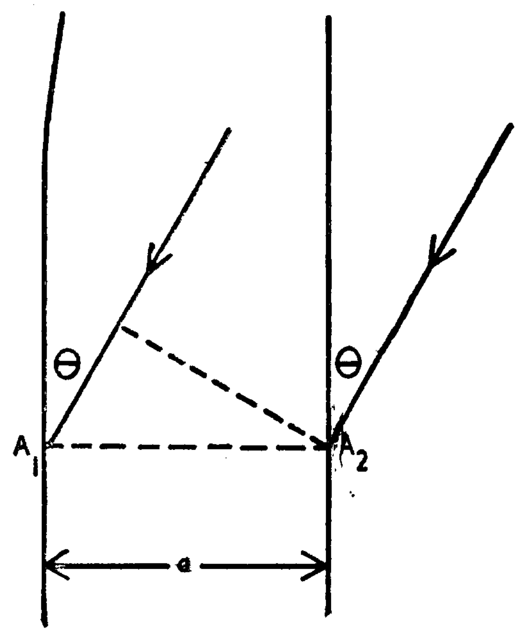

Fig. 4.

If we now have a phase-sensitive detector which gives an output only when the two phases coincide, then by introducing a known phase shift into the output from one aerial we can measure the received phase difference and hence

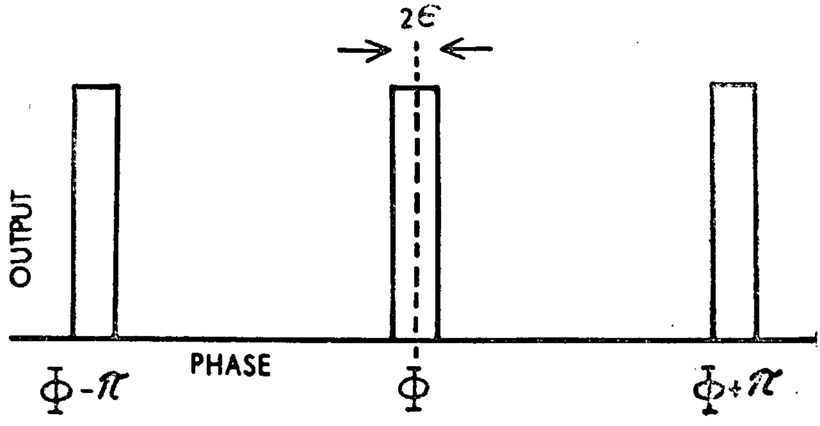

Fig. 5.

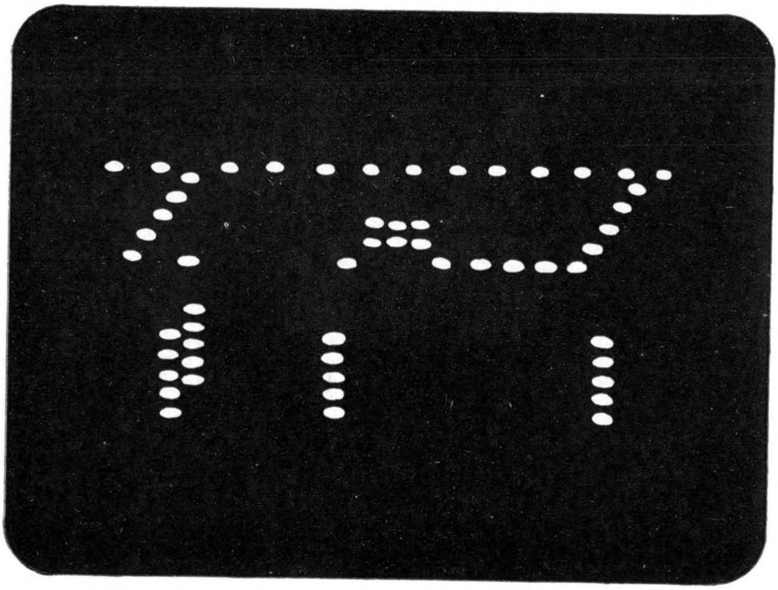

Fig. 2.

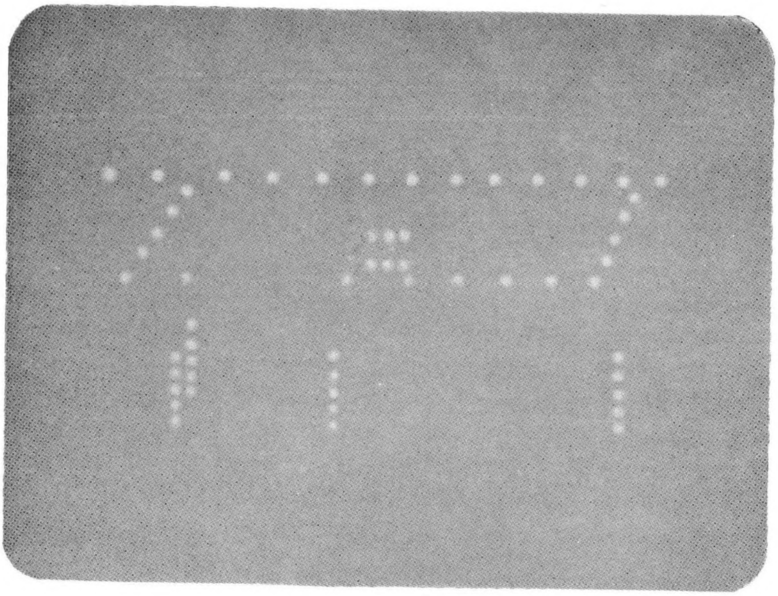

Fig. 3.

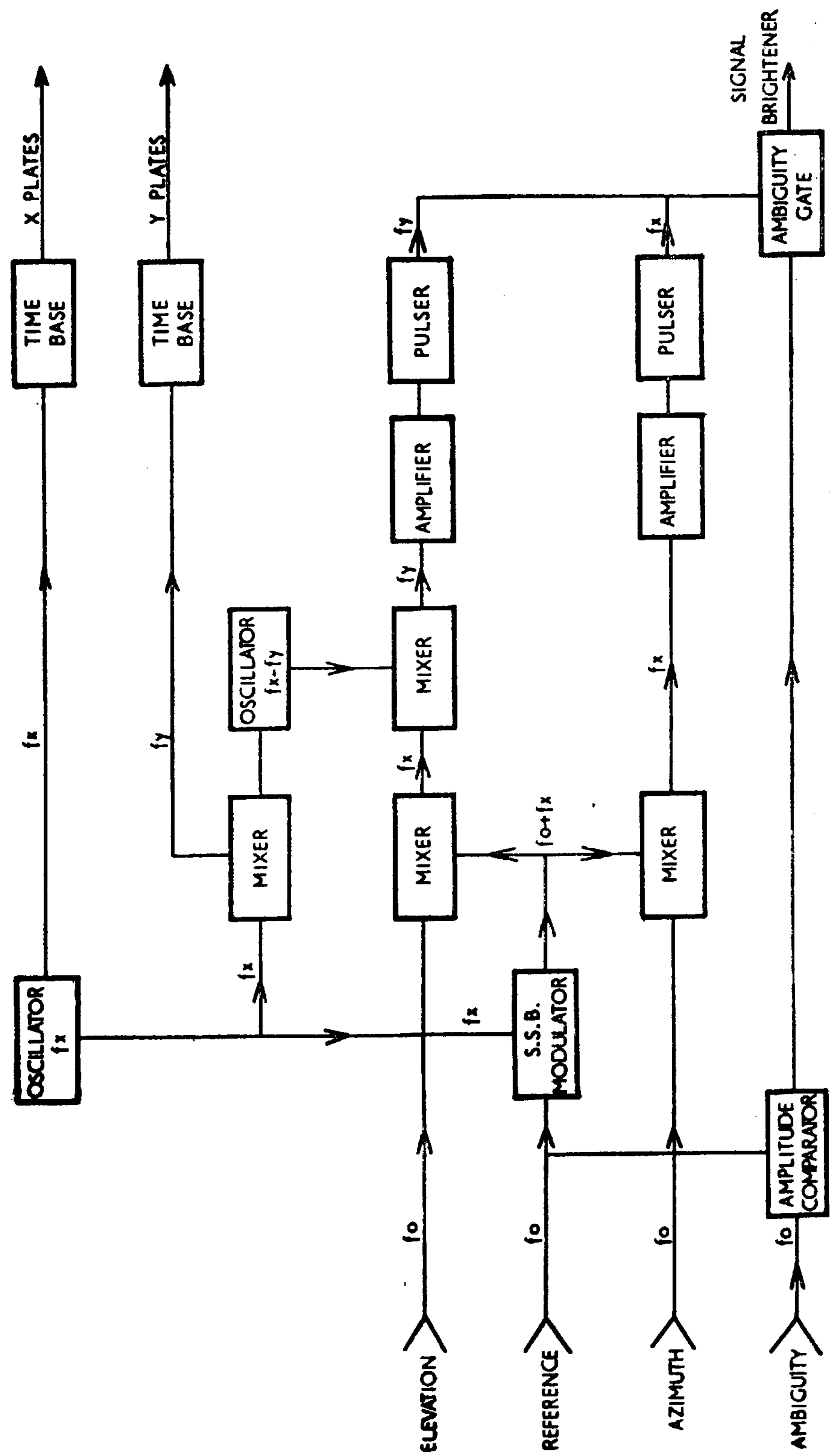
X PLATES
Y PLATES
TIME BASE
TIME BASE
OSCILLATOR fx
OSCILLATOR fx-fy
MIXER
MIXER
MIXER
MIXER
AMPLIFIER
AMPLIFIER
PULSER
PULSER
AMBIGUITY GATE
SIGNAL BRIGHTENER
S.S.B. MODULATOR
AMPLITUDE COMPARATOR
fx
fy
fo+fx
fo
ELEVATION
REFERENCE
AZIMUTH
AMBIGUITY

Fig. 6.

the direction θ. If the detector characteristic is as shown in Fig. 5, where an output is only obtained with a phase difference of $\pm \varepsilon$, where ε is small, then an output is only obtained when

$$\Phi - \varepsilon \leq \frac{2\pi\, a \sin\theta}{\lambda} + \psi \leq \Phi + \varepsilon,$$

where ψ is the phase shift introduced into one aerial.

An ambiguity arises when

$$\frac{2\pi\, a \sin\theta}{\lambda} \geq \pi$$

that is to say, a difference δ in the transmission paths to the two aerials gives the same phase difference as a difference in path length $\lambda/2 + \delta$. The simple system is therefore limited to an angle θ having a maximum value given by

$$\frac{2\pi\, a \sin\theta\,\mathrm{max.}}{\lambda} \leq \pi$$

If θ max. is defined by operational requirements, the aerial spacing is then defined by

$$\frac{a}{\lambda} \leq \frac{1}{2 \sin\theta\ \mathrm{max.}}$$

A PRACTICAL SYSTEM

Figure 6 shows a block schematic diagram of a shipborne equipment based on the scheme outlined above. Four horns are shown, a reference one which is compared with two others for azimuth and elevation information respectively, and one which is used for ambiguity resolution. The input frequency f_0 to the reference horn is passed through a single-sideband modulator, which can be a rotating phase shifter, but more probably will be a ferrite subjected to an attenuating field of frequency f_x. The output from this, at frequency $f_0 + f_x$ is mixed with the input from the azimuth horn and a signal frequency f_x is obtained, the phase of which, relative to the modulating voltage, is proportional to the phase difference between the signals arriving at the two horns. This phase angle can be displayed by generating a pulse at some convenient point on the sine wave such as the zero voltage point and using it to brighten a trace on a cathode-ray tube the horizontal scan of which is derived from the modulating voltage f_x By suitably adjusting the phase of the scan, the spot may be made to appear at a point corresponding to its actual position in azimuth relative to the ship.

By duplicating this process in elevation at a different frequency f_y and arranging to brighten the tube only when a signal appears in both scans, one can obtain a raster on which the signals appear on the tube screen in the correct relative positions to form a visual picture of the marker points.

To avoid a second single-sideband modulator, the modulated reference signal and the elevation signal are passed through a mixer and an output at frequency f_x obtained as before; this is then mixed with an oscillator at frequency $f_x - f_y$ and an output at frequency f_y obtained, the phase of which is compared, as before, with a vertical scan at frequency f_y, derived by mixing the two oscillators at frequencies f_x and $f_x - f_y$. The choice of frequencies f_x and f_y is discussed later.

As explained earlier, ambiguities will occur at angles greater than that necessary to give a phase difference of π radians between the inputs to the horns, and in the practical case this angle coincides with that at which the radiation pattern of the horns falls by about 3db. By incorporating a fourth horn with a wider coverage and a gain such that its pattern intercepts that of the main horns at about the 6db level, a gate circuit can be arranged so that a signal is only accepted when the amplitude from the main horn exceeds that from the ambiguity resolver. Alternatively, the peak output from the ambiguity horn may be used to determine a bias level which must be exceeded by that from the other horns before a signal is accepted.

These amplitude comparisons can be very much simplified by making use of the switching modulation of the « picture » transmitter to enable simple crystal-video circuits to be used.

The choice of frequencies f_x and f_y is governed by the discrimination required in each direction and the number of complete pictures required per second. It is feasible to provide a resolution of one hundredth of the picture width in each direction, and if 0.1 microsecond is chosen as the shortest pulse that can be handled by simple video circuits, then the horizontal sweep will occupy 10 microseconds giving a repetition frequency of something under 100 Kc/s when allowance is made for a safety margin at each end of the sweep. From this it follows that the vertical scan frequency will be something less than 1 Kc/s. Assuming 100 marker points on the ground switched at a rate of 100 c/s, then a complete scan will occupy one second and each target point will be scanned approximately ten times during this period.

A transmitter power of 30 milliwatts gives a range of about 3 Km for the system even when 30db path loss is experienced due to fog absorption and attenuation losses, if horns of 3 ins by 4.5 ins are employed.

The shipborne horn assembly will be rotatable to lock in any required direction. It will, in effect, present a limited area of picture, as would a television camera at the same point. The preliminary work has chosen to limit the vertical angle covered to $\pm$ 6° and the horizontal angle to $\pm$ 12°. The resolution of the system is therefore to 0-12° in the vertical plane and 0-24° in the horizontal. The signals from two transmitters subtending lesser angles than these will overlap on the system indicator.